The Nanotechnology Challenge

CREATING LEGAL INSTITUTIONS FOR UNCERTAIN RISKS

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How Scientific Evidence Links Attitudes to Behaviors

James N. Druckman and Toby Bolsen

Nanotechnology has the potential to revolutionize applications across a dizzying array of fields, including medicine, energy, cosmetics, computing, agriculture, and aerospace. Although many of these applications have become publically available, even more have yet to hit the marketplace. The ultimate plight of these technologies depends, in large part, on public acceptance and usage. New technologies will not find commercial acceptance or overcome regulatory hurdles if they are not embraced or at least tolerated by customers.

A growing body of work explores the determinants of attitudes or opinions about nanotechnology (e.g., Cobb & Macoubrie, 2004; Lee et al., 2005; Scheufele & Lewenstein, 2005; Lee & Scheufele, 2006). Yet the bulk of this work overlooks two important dynamics. First, public opinion analysts often strictly distinguish the role of factual information (e.g., knowing a nanometer is a billionth of a meter) from the impact of alternative processes such as framing (e.g., being told that nanotechnology has implications for energy costs). This is unfortunate because much of the information citizens receive melds frames and facts, as when an energy frame provides facts about cost savings. How does adding factual content to a frame influence public reactions? Second, extant work rarely explores the relationship between nanotechnology opinions and willingness to actually use nanotechnology – despite the well-documented disconnect between attitudes and behaviors, more generally. When do nanotechnology attitudes (e.g., support for investment and usage) predict behaviors (e.g., willingness to personally use)?

We address these questions by offering a psychological theory of opinion formation and behavior and test our expectations with an experiment. We find that adding factual content (e.g., a specific citation to a scientific study) to framed arguments has no effect on attitudinal support for a nanotechnology application. However, adding such information significantly strengthens the impact of the frame on behavioral intentions. Moreover, it heightens the connection between attitudes and behaviors by making respondents more certain of their attitudes. In short, adding factual evidence to frames (1) does not affect attitudes in ways that differ from analogous frames without facts, but it does (2) strengthen the effect of the frames on behavioral intentions, and (3) increase the correlation between attitudinal support and behavioral intention because individuals become more certain of their attitudes. These results have important implications for understanding public reactions to nanotechnology; it is critical to distinguish attitudinal support from behavioral intentions, and moreover, facts have differential effects on attitudes and behaviors.

NANOTECHNOLOGY ATTITUDES AND BEHAVIORS

Over the last several decades, scholars have developed a field of study that explores how citizens perceive the risks and benefits associated with new products (e.g., Currall et al., 2006). It is within this domain that most work on nanotechnology attitudes situates itself (e.g., Cobb & Macoubrie, 2004; Macoubrie, 2006). A long-standing theme of this literature is the need to inform the public about facts surrounding new technologies; that is, to make citizens scientifically literate (e.g., Miller, 1998; Bauer et al., 2007). New factual information presumably facilitates accurate assessment of risks and benefits and generates "support for science and technology" (Gaskell et al., 1999, p. 386; Nisbet & Goidel, 2007, p. 421; Miller, 1998; Sturgis & Allum, 2006). More recent work questions the scientific literacy approach, instead emphasizing how other factors shape emergent technology opinions, including values, trust in science, and the framing of the technologies. These factors seem to matter more than basic factual knowledge because people often possess little knowledge about the technologies and have scant motivation to learn more. Scheufele and Lewenstein (2005, p. 660) explain that "developing an in-depth understanding would require *significant* efforts on the part of ordinary citizens [and] the pay-offs . . . may simply not be enough" (emphasis in original; also see Lee et al., 2005; Scheufele, 2006; Kahan et al., 2007, 2008). Consequently, people form their opinions in a less deliberate manner that does not involve careful integration of factual information. Instead, they rely on shortcuts or heuristics that require less of them when forming opinions.

Most of these heuristic factors involve information that lacks clear factual content, with perhaps the most notable example being influence from framed communications. In their study of nanotechnology attitudes, Scheufele and Lewenstein (2005, p. 660) explain, "opinions will be influenced by factors *other* than [factual] information, such as . . . the way mass media frame issues . . ." A framing effect occurs when, in the course of describing a new technology, a speaker's emphasis on a subset of potentially relevant considerations causes individuals to focus on those considerations when constructing their opinions, which may in turn lead to a change in overall support (Druckman, 2001, pp. 226–231). For example, a news article on nanotechnology emphasizing consequences for human health may cause readers to focus on health risks and become less supportive, whereas an article focusing on consumer good production may lead readers to attend to those benefits and become more supportive. While numerous studies show that alternative frames can significantly shape nanotechnology opinions (e.g., Cobb, 2005; Scheufele, 2006; Kahan et al., 2008; Nisbet & Mooney, 2007), virtually all of this work employs frames that include no explicit factual content.[1]

For us, a fact is something that verifiably exists and has some objective reality (Merriam-Webster Online Dictionary). Facts come in a wide variety of forms and, on most issues, are ever-present (e.g., Shapiro & Block-Elkon, 2008). We (narrowly) focus on facts in the guise of "scientific *evidence*" that report a verified observation (e.g., an experimental outcome). For example, the statement "A recent study reported that material akin to that found in many nanotechnology applications was present in some rivers of Britain" constitutes a fact because it reports the confirmed result of a study. Facts differ from value judgments that contain subjective elements, often about prioritizing distinct considerations (e.g., Fairbanks, 1994). For example, the *claim* that "the most important implication of nanotechnology concerns its impact on the environment" contains no verifiable content and, as such, amounts to a value judgment.[2]

As mentioned, frames often do not include factual content – at least in the sense of reference to a confirmed scientific study – and thus are analogous to value judgments/claims insofar as they prioritize a consideration (which may but need not be a value) (e.g., Nelson et al., 1997; Berinsky & Kinder, 2006). Here are two examples of nanotechnology application frames that lack specific factual content: the first highlights a consideration – energy costs and availability – generally viewed as pro-nanotechnology (because nanotechnology reduces costs), whereas the second emphasizes a con-nanotechnology – health risks – consideration (because of the uncertain health consequences).

- Energy/costs availability (pro-nanotechnology): "Most agree that the most important implication of carbon nanotubes (CNTs) concerns how they will affect energy cost and availability."
- Potential health risks (con-nanotechnology): "Most agree that the most important implication of CNTs concerns their unknown long-run implications for human health."

[1] One exception is Cobb (2005), who finds that factually oriented frames have larger effects than those that lack facts.

[2] Our focus on the relative impact of facts as scientific evidence follows a long-standing concern of risk analysts. Fischhoff (1995, p. 139) explains, "Risk analysts have fought hard to create a clear distinction between the facts and values of risk management." That said, we recognize that not all accept the fact-value distinctions – those readers can view our work as instead focusing on "evidence" and "claims."

Analogous arguments that contain scientific evidence (i.e., what we are calling a fact) might cite a specific study:

- Energy/costs availability (pro-nanotechnology): "A recent study on cost and availability showed that CNTs will double the efficiency of solar cells in the coming years."
- Potential health risks (con-nanotechnology): "A recent study on health showed that mice injected with large quantities of CNTs reacted in the same way as they do when injected with asbestos."

These latter two statements are, in essence, frames with facts because they emphasize the relevant considerations of energy costs and health risks, respectively (by citing the studies in these areas). Nisbet and Scheufele (2009, p. 5) explain, "Framing is an unavoidable reality of the science communication process. Indeed, it is a mistake to believe there can be 'unframed' information." In other words, the evidentiary statements are a type of "fact frame" as compared with the first two examples, which are "factless frames" (which, as mentioned, are common in most studies; c.f., Cobb, 2005).

How will adding factual content – specifically a reference to a scientific study – influence the attitudinal impact of a frame? Chong and Druckman's (2007a) theory of framing suggests that, when it comes to attitudes (e.g., general support for nanotechnology), only motivated and able individuals scrutinize a frame's content such that the inclusion of facts enhance its effect. As explained, we expect no such motivation or ability in the case of nanotechnology, and thus we expect that facts do not significantly affect opinions, beyond the effects of a frame absent factual content.[3] Frames that contain factual content do not have a significantly greater impact on attitudes than frames without factual information (hypothesis 1). This prediction echoes Lakoff's (2004, p. 17) statement that "People think in frames . . . To be accepted, the truth must fit people's frames. If the facts do not fit a frame, the frame stays and the facts bounce off" (also see Eagly & Chaiken, 1993, p. 327; Fazio, 2000, p. 14; Kunda, 2001, p. 16). We test this hypothesis in two ways: (1) by comparing whether a frame containing factual content supportive of (opposed to) a new technology has a greater effect on opinions than analogous supportive (opposing) frames that lack factual content, and (2) by exploring whether a supportive (opposing) frame with a fact overpowers a competing opposing (supportive) frame that lacks factual content.

When it comes to *behavior* (i.e., willingness to use the technology), however, we suspect that adding scientific evidence may matter. To see why, first note that, in many cases, attitudes do not correlate with related (intended) behaviors – as Wicker (1969, p. 65) famously stated, "it is considerably more likely that attitudes

[3] Similarly, Petty and Wegener (1999, p. 42) explain that when motivation and/or ability are low, individuals examine "less information . . . or examine . . . information less carefully."

will be unrelated or only slightly related to overt behaviors" (for a review see Miller & Peterson, 2004; Ajzen & Fishbein, 2005). Forty years of subsequent research, following Wicker's statement, identifies various factors that enhance the attitude–behavior connection. One such factor is attitude strength: "empirical research has shown that attitude strength – no matter how it is assessed – tends to moderate the attitude–behavior relation as expected. That is, strongly held attitudes generally predict behavior better than weakly held attitudes" (Fishbein & Ajzen, 2010, p. 261). Although there exist various conceptualizations of attitude strength (e.g., Miller & Peterson, 2004; Visser et al., 2006), the one relevant here is *certainty of or confidence in* one's attitude. Individuals who have confidence in their attitudes act on those attitudes; in contrast, individuals who lack confidence are "hesitant to use their attitudes to guide behavior" (Visser et al., 2006, p. 40–41; also see Krosnick & Smith, 1994, p. 284; Cooke & Sheeran, 2004; Druckman, 2004; Glasman & Albarracín, 2006).

Attitude strength tends to grow when individuals think about their attitudes or have attitude-relevant experiences (e.g., Krosnick & Smith, 1994; Visser et al., 2006; Glasman & Albarracín, 2006, p. 782). It also "is determined at least in part by the volume and perceived reliability of attitude-supportive information stored in memory ... when an attitude is supported by a sufficiently large base of *reliable* information, people will feel confident that their attitude is valid" (emphasis added, Visser et al., 2006, p. 38–39; also see Berger, 1992). Adding factual content to a frame likely enhances the perceived dependability of the information and thus increases certainty and, subsequently, the attitude–behavior link.[4] We predict that frames with factual content – citing scientific evidence – will thus (1) increase attitude certainty (hypothesis 2a), (2) increase the link between attitude and behavior (hypothesis 2b), and, as a result, (3) have a greater effect on behaviors (e.g., frames lacking facts will not influence behaviors because people will not be willing to act per se on their attitudes, even though those attitudes were affected by frames) (hypothesis 2c).

Psychologically, our argument suggests that individuals form their attitudes based, in part, on the recently received frame. Individuals lack sufficient motivation and ability to downgrade frames that lack reliable information, and thus frames with or without facts have analogous attitudinal effects: individuals use them similarly as a basis for attitude formation.[5] However, the addition of facts makes individuals more certain or confident about the attitude they form based on the frame (because the facts offer more reliable/specific evidence). This coheres with the finding that

[4] Few framing studies, in general, explore behavior (as opposed to attitudes) (however, see, e.g., Vishwanath, 2009; Bolsen, 2010).

[5] Increased motivation and ability can itself influence attitude strength; however, we focus here on how reliable information does so, even in the absence of motivation and ability.

adding quantitative evidence to a statement typically does not enhance its persuasiveness (O'Keefe, 1998, p. 72; 2002b, pp. 229–230) but may constitute "explicit supporting argumentation [that] directly enhances belief in the relevant . . . argument" (O'Keefe, 2002a, p. 71; also see O'Keefe 1998, 2002b, pp. 186–187).

EXPERIMENTAL PARTICIPANTS, PROCEDURE, AND DESIGN

To investigate our hypotheses, we conducted an experiment that focused on a nanotechnology application: carbon nanotubes (CNTs).[6] CNTs are tiny graphite with chemical properties that, among other applications, facilitate the conversion of sunlight into electricity. Although CNTs came to prominence in the early 1990s, the mass public knows little of them, with 49% reporting that they have heard nothing about them (Peter D. Hart Research Associates, Inc., 2008). Our specific experiment took place in the context of an exit poll on Election Day in 2008. We opted for this approach for two reasons. First, it allowed us to include a heterogeneous sample of respondents. Second, and more importantly, it enabled us to provide perspective to this relatively unfamiliar technology by situating it within a context. Specifically, we explained that CNTs are likely to receive considerable attention during the next President's term (which coheres nicely with the attention energy received during the campaign). Although in some sense unusual, we believe this enhances experimental realism, compared with confronting respondents with a novel technology with no context whatsoever.[7]

We implemented the survey experiment by assembling 20 teams of student pollsters. We then randomly selected polling locations throughout the northern part of Cook County, Illinois. Each polling team spent a randomly determined 2- to 3-hour daytime period at their polling place. A pollster asked every third voter to complete a self-administered questionnaire in exchange for $5. Our sample ended up consisting of 621 individuals; their demographic profile appears in Table 4.1. The table shows that the respondents come from fairly diverse backgrounds; although, as would be expected in northern Cook County, the sample is skewed toward liberal and educated individuals.

The Election Day survey provided respondents with a description of CNT technology:

> One of the most pressing issues facing the nation – as has been clear from the election – concerns the limitations to our energy supply (e.g., with regard to coal,

6 The study also included an experiment focusing on genetically modified food. We found no evidence of spill-over effects from the two experiments. For details on the genetically modified food study, see Druckman and Bolsen (n.d.).

7 Perhaps the main disadvantage of our approach is that exit poll surveys need to be short, thereby constraining the number of items we could include.

TABLE 4.1. *Profile of sample*

Variable	Scale (Overall distribution)	Average (SD)
Political Ideology (Conservativeness)	1 (very liberal) = 17% (107) (total N = 616) 2 = 26% (156) 3 = 18% (111) 4 (moderate) = 20% (124) 5 = 9% (57) 6 = 6% (36) 7 (very conservative) = 4% (25)	3.12 (1.64)
Ethnicity (Minority Status)	White = 69% (409) (total N = 595) African Americans = 15% (87) Asian Americans = 5% (31) Hispanic =2% (13) Other = 4% (23) Prefer not to answer = 5% (32)	n/a
Sex (Female)	Male = 42% (251) (total N = 592) Female = 58% (341)	n/a
Age	1 (18–24) = 27% (160) (total N = 595) 2 (25–34) = 15% (89) 3 (35–44) = 14% (82) 4 (45–54) = 15% (90) 5 (55–64) = 13% (79) 6 (65–74) = 10% (57) 7 (75+) = 6% (38)	3.27 (1.93)
Education	1 (less than high school) = 1% (5) (total N = 595) 2 (high school) = 9% (53) 3 (some college) = 30% (179) 4 (year college degree) = 27% (163) 5 (advanced degree) = 33% (195)	3.82 (1.01)
Newspaper Reading	1 (never) = 5% (31) (total N = 619) 2 = 10% (64) 3 = 10% (60) 4 (a few times a week) = 18% (114) 5 = 13% (79) 6 = 11% (70) 7 (everyday) = 33% (201)	4.87 (1.93)

SD, standard deviation.

> oil, and natural gas). One approach to addressing this issue is to rely more on carbon nanotubes, or CNTs. CNTs are tiny graphite with distinct chemical properties. They efficiently convert sunlight into electricity and thus serve as an alternative to coal, oil, and natural gas. The uncertain long-term effects of CNTs are the subject of continued study and debate.

Respondents then were randomly assigned to one of nine conditions (used to test our hypotheses) that offered distinct descriptions of CNTs (beyond what they read in the preceding description). Specifically, we used the four bulleted statements provided previously, allowing us to have pro (i.e., energy costs/availability) and con (i.e., potential health risks) factless frames and pro and

TABLE 4.2. *Experimental conditions*

	No fact frame	Pro fact frame	Con fact frame
No Factless Frame	(*Condition* 1) (N = 69)	(2) (N = 69)	(3) (N = 72)
Pro Factless Frame	(4) (N = 71)	(5) (N = 68)	(6) (N = 67)
Con Factless Frame	(7) (N = 70)	(8) (N = 67)	(9) (N = 68)

con fact frames. As mentioned, the fact frame statements contain verified scientific evidence.[8]

Table 4.2 presents the particular conditions (with the Ns appearing in the cells). Our first condition served as a baseline (frameless/fact-free) control; these respondents read only the brief background description and then answered our dependent variable questions (that we discuss momentarily). In conditions 4 and 7, respondents – after reading the brief descriptions – received the pro frame (without fact) or the con frame (without fact) (e.g., see the previously presented bulleted statements). These conditions mimic many framing experiments that expose participants to one frame or another (without factual content), with the expectation of the frames pushing opinions in distinct directions. Conditions 2 and 3 matched conditions 4 and 7; however, instead of the frame (without fact) statement, respondents received the factual (frame) statement. If facts have an additional effect on attitudes (counter to our prediction) or behavior (consistent with our predictions), then the effects from conditions 2 and 3 (facts alone) should significantly exceed those found in conditions 4 and 7 (frames sans facts), respectively.

The other conditions combine multiple statements. Conditions 5 and 9 offer respondents both frames without facts and the factual evidence frames.[9] Conditions 6 and 8 introduce facts that contradict the concomitant framed (without fact) statement; for example, the pro-frame-con fact condition (6) read "Most agree the most important implication . . . concerns . . . energy costs . . . A recent study, unrelated to energy costs, showed that mice . . ."[10] These two conditions directly pit the relative power of contrasting frames without facts against framed facts, allowing us to assess

8 We pre-tested these and other statements (N = 34) with participants who did not take part in the main study. We used the pre-test to ensure that individuals viewed the statements as pointing in the direction we assumed (i.e., pro or con nanotechnology) and as containing facts or not (i.e., we asked pre-test participants to evaluate the extent to which distinct statements contained verifiable statements with an objective reality). Further details on this and other pre-test assessments are available from the authors. Also note that for the factless statements, we included a consensus endorsement to ensure its credibility (O'Keefe, 2002b, p. 150).

9 In all cases, the frame (without fact) appeared first.

10 We pre-tested the exact wordings of all conditions to ensure adequate flow.

whether frames that provide verifiable evidence overpower analogous arguments that lack factual evidence.

After reading the given CNT description, participants responded to our main dependent variables. Our attitudinal question asked participants to rate on a 7-point scale the extent to which they, generally, oppose or support "using CNTs," with higher scores indicating increased support (e.g., 1 = oppose strongly, 4 = not sure, 7 = support strongly). Next came our measure of attitude strength or certainty, in which we asked respondents to rate how strongly they felt about their attitude on a 7-point scale, with higher scores indicating increased certainty.[11] For our behavior variable, we followed others by focusing on a behavioral intention, which indicates the "person's readiness to perform a behavior . . . [it] is a person's estimate of the likelihood or perceived probability of performing a given behavior" (Fishbein & Ajzen, 2010, p. 39; also see Sheeran, 2002; Ajzen & Fishbein, 2005, p. 188).[12] We asked respondents to rate how likely they would be to use CNTs (e.g., personally), with higher scores indicating increased likelihood (e.g., 1 = definitely not use, 4 = not sure, 7 = definitely use).

RESULTS

We begin by presenting, in Figure 4.1, the distributions of each dependent variable: attitudinal support for CNTs, attitude certainty, and likelihood of using CNTs (i.e., behavior).[13] When it comes to attitudes and behavior, nearly 40% opted for the mid-point of 4, which was labeled "not sure" – this undoubtedly reflects lack of knowledge and general ambivalence. The attitude certainty score distribution reveals a more varied range, although the modal response also is a 4. Perhaps the most relevant aspect of the figure is that the attitude line drops below the behavior line when it comes to the low scores (i.e., 1, 2) but exceeds it on the higher scores (e.g., 6, 7). In other words, people are more willing to offer attitudinal support than commit to actually using CNTs; this is reflected in a significant difference in the respective scores of 4.63 (standard deviation [SD] = 1.56; 619) and 4.14 (SD = 1.62; 616) ($t_{605} = 7.75$, $p \leq .01$ for a one-tailed test). (The average certainty score is 4.34 [1.80; 619].)

[11] Our particular measure of certainty differs from that of others who ask about "certainty" or "confidence." Our measure is more general and may envelope related attitude strength features, such as importance (see Visser et al., 2006, pp. 20, 51 on how importance and certainty generate similar effects, particularly regarding attitude-behavior connections; however, also see Visser et al., 2003).

[12] Ajzen and Fishbein (2005, p. 188) explain that "intentions to perform a behavior, rather than attitude, is the closest cognitive antecedent of actual behavioral performance . . . This implies that we should be able to predict specific behaviors with considerable accuracy from intentions to engage in the behaviors under consideration."

[13] For the purposes of the figures, we rounded the scores of the few respondents who chose mid-points on the scales (e.g., 2.5). Also, for presentational purposes, we treat the dependent variables as interval levels throughout; however, our results are robust to treating them as ordinal.

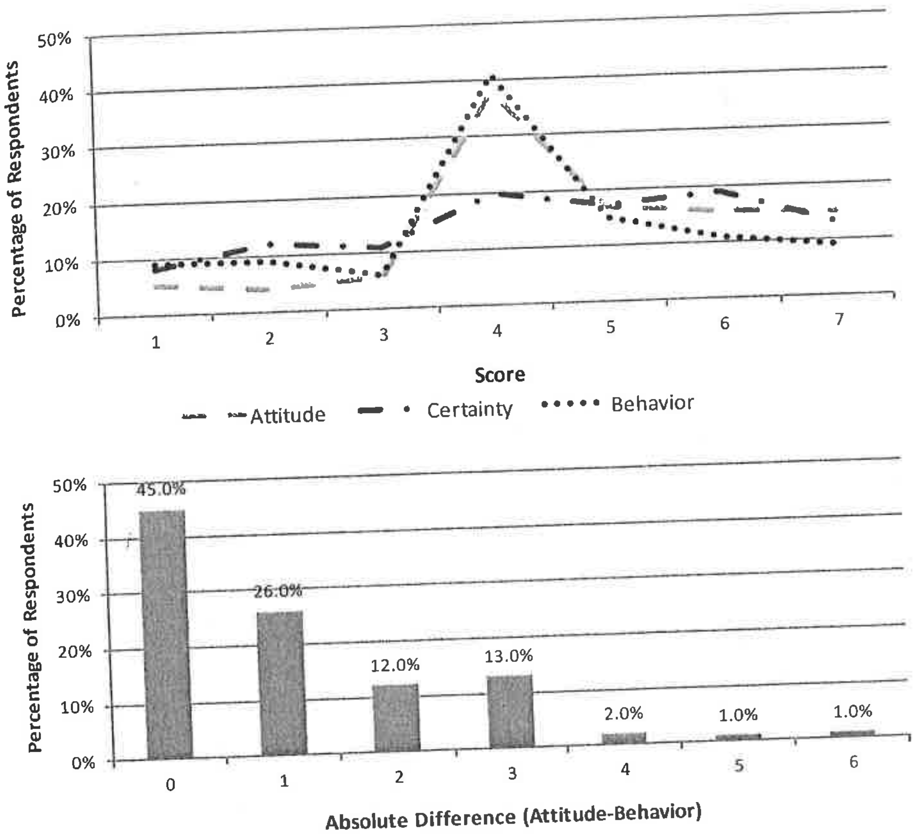

FIGURE 4.1. Distributions of CNT attitude, certainty, and behavior.

What this means is that, as expected, there exists some disconnect between attitudes and behaviors; to explore the range of this disjuncture, we take the absolute difference between each respondent's attitude and behavior scores. Figure 4.2 presents the distribution of those scores – for example, 45% of respondents registered exactly the same attitude and behavior scores, whereas only 1% provided responses to the two questions at each end of the 7-point continuum. The average difference is 1.06 (SD = 1.26; 616).[14] (Because these are absolute differences, the figure does not provide insight into which score – behavior or attitudes – was greater, but as mentioned, on average, attitude scores are higher.) Although the attitude–behavior differences are not extreme, they are nonetheless plainly evident. The question is whether the difference declines for those who express more certainty in their attitudes as driven by exposure to factual information.

We now turn to testing our hypotheses. We focus on the mean values of the dependent variables, by condition. We do this for simplicity's sake; the results are

[14] The correlation between attitude and behavior is .51.

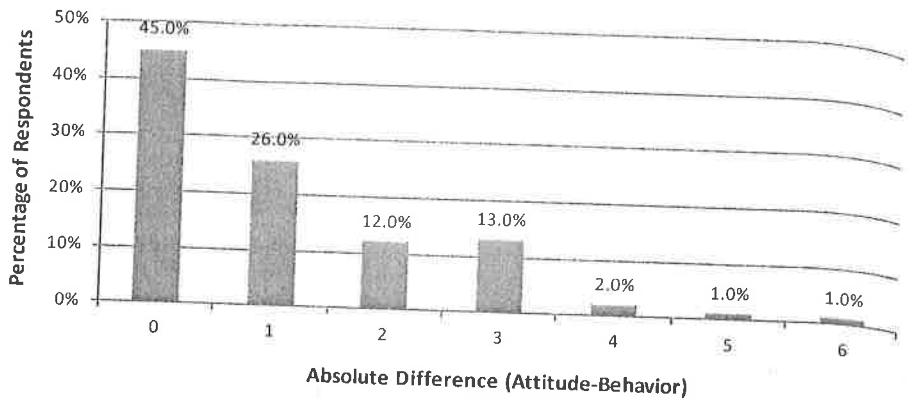

FIGURE 4.2. Distribution of attitude–behavior differences.

robust to multivariate analyses that include demographic controls.[15] Specifically, for each of our dependent variables, we report the percentage shift in the variable for each given condition relative to the control group (where respondents received no frames or facts).[16] The precise means and SDs for each dependent variable by condition appear in the Appendix.

In Figure 4.3, we plot the results for attitudinal support. This and all other subsequent figures use the abbreviations of "Eg" for energy, "Ht" for health, "Fr" for frame, and "Ft" for fact; they also label the conditions consistent with numbers in Table 4.2. Reading from left to right, we report results for the pro (energy) conditions, followed by the con (health) conditions, and then the mixed pro-con conditions.

The attitudinal results are stark. First, in every case, the pro factless frames, fact frames, and factless frame-fact frame combinations generate significantly more support (than the control group), whereas the con conditions do the reverse. Second and more importantly, adding facts does not significantly (e.g., at the .10 level) increase the impact of the frames. Although there is marginal evidence of a slightly larger effect from the fact frames (conditions 2 and 3), compared with the factless frames (conditions 4 and 7), the differences are nowhere near significant. For example, the CNT health risk factless frame (condition 7) alone versus the fact frame alone condition (condition 3) produced the largest difference between these conditions (-15.5% versus -18.8%) and the difference is far from significant ($t_{140} = .73$, $p \geq$

[15] We confirmed that random assignment to experimental conditions was successful in terms of analogous distributions of respondents in each condition. This ensures that mean differences across conditions are not spuriously due to confounding variables (at least those that we measured). Also, our survey included other measures shown to affect nanotechnology opinions, such as trust in science, general science knowledge, and certain values. Inclusion of these measures in multivariate analyses does not alter the results we report here. Also, the impact of these variables is of marginal interest, given the not perfectly representative nature of our sample; nonetheless, for details on the impact of such controls, see Druckman and Bolsen (2011).

[16] See Chong and Druckman (2007b) on using a control group as the appropriate point of comparison.

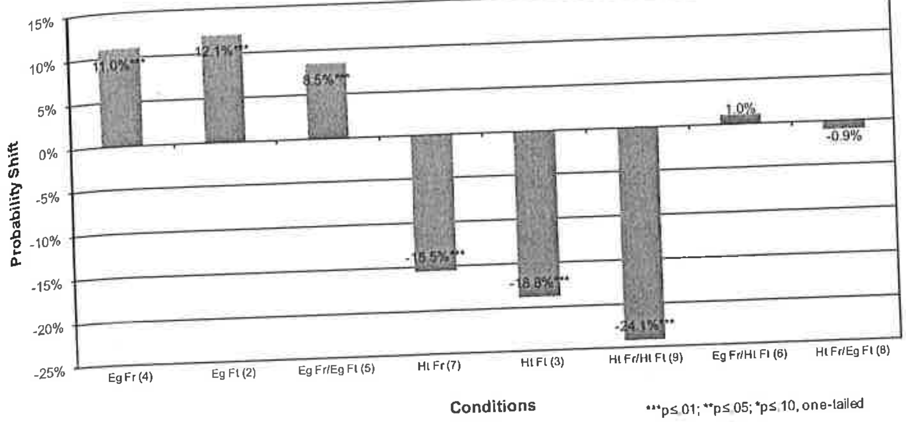

FIGURE 4.3. Attitudes toward CNTs.

.20 for a one-tailed test). Additionally, opposing fact frames do not overpower frames without facts – the mixed conditions (6 and 8) never produce significant effects (at anywhere near the .10 level), further supporting the finding that adding facts does little. Instead, the frames cancel each other out regardless of factual content.[17]

In sum, we find support for hypothesis 1: frames – with or without facts – substantially affect *opinions*, but adding reference to a factual scientific study does not enhance the effect. To be clear, the fact frames have effects. The fact frame alone statements (conditions 2 and 3) significantly move opinions and successfully counteract the factless frames (conditions 6 and 8). What our results suggest is that receiving factual information does not appear to have a greater impact on attitudinal support than exposure to analogous statements without factual content.[18]

When we turn to attitude certainty and behavior, we see a very different story. Figure 4.4 shows that, consistent with hypothesis 2a, adding factual content to the frames significantly increases the certainty with which individuals hold their attitudes, relative to the control groups (and the analogous factless frame groups). This is evident in every case, and interestingly, although not significantly different, the

17 Two other dynamics are worth noting. First, although the most substantial effect occurs for the con-factless frame and fact-frame combination condition (condition 9), this likely reflects the mix of both statements rather than just the additional fact. Indeed, the effects from this combination condition are larger than the fact-frame alone condition (condition 3), as well as the factless-frame alone condition (condition 7). The con health factless frame-fact frame condition (condition 9) is significantly greater than the factless frame condition (condition 7) ($t_{136} = 1.96, p \leq .05$ for a one-tailed test) and marginally significantly greater than the fact frame condition (condition 3) ($t_{138} = 1.22, p \leq .12$ for a one-tailed test). Second, the negative conditions uniformly displayed larger effects than the positive conditions, perhaps echoing the well-known negativity bias (Rodriguez, 2007, pp. 478, 493).

18 As mentioned, Cobb (2005) reports, in contrast to our results, that fact frames tend to have greater effects on attitudes. His design differs from ours, however, insofar as he does not strictly compare fact frames with factless frames along the same dimensions of consideration.

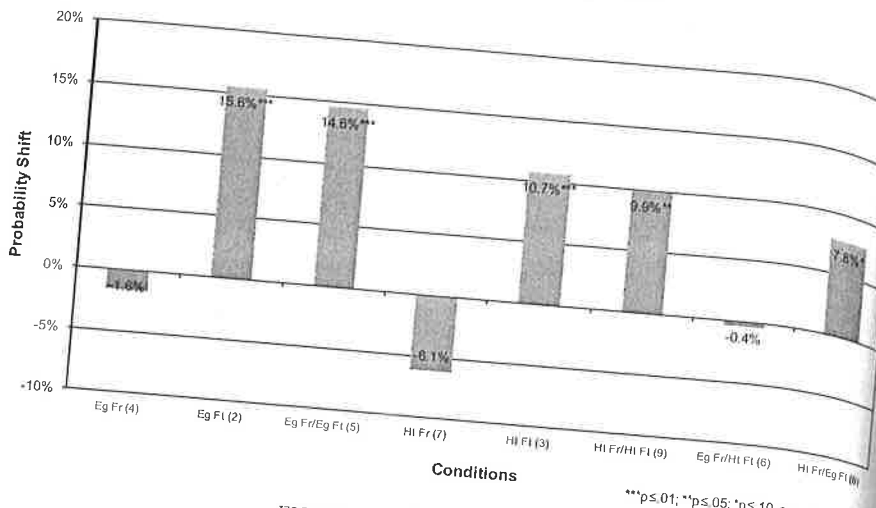

FIGURE 4.4. Attitude certainty.

largest effects occurred when the fact frame was not echoed by a consistent factless frame (i.e., compare conditions 2 and 3 with conditions 5 and 9, respectively). However, when the fact frame is challenged by a factless frame in the other direction, the results are mixed. When the con health fact frame is countered by the pro factless energy frame, there is no impact on certainty (condition 6), yet there is a marginal effect of the pro energy fact frame when it is challenged by the con factless health frame (condition 8). These latter results – of two-sided information vitiating the fact frame effect – are consistent with Glasman and Albarracin's (2006, p. 782) point that "*one-sided attitude-related information* can also increase attitude confidence [certainty] because univalent attitudes create less doubt than more complex ones" (emphasis in original).

We see the same pattern of results when we explore behavior – willingness to use CNTs – in Figure 4.5. Again, we see significant effects on behavior *only* in the conditions where fact frames appeared (i.e., conditions 2, 3, 5, & 9). The CNT pro-factless frame by itself (condition 4) increases willingness to use CNTs by 5.6%, and the con-factless health frame alone (condition 7) decreases willingness to use CNTs by 2.4%, but these differences are not significantly different from the control group. By contrast, exposure to a fact frame, alone or in combination with a factless frame, significantly increases intentions to use CNTs in the pro conditions (13.3% and 12.2% in conditions 2 and 5, respectively), and significantly decreases intentions to use CNTs in the con conditions (−11.9% and −9.6% in conditions 3 and 9, respectively). In the case of behavior, unlike certainty though, both mixed conditions (i.e., 6, 8) display no significant results. Thus it appears as if unidirectional fact frames move behavior, but any other mix (i.e., factless frames, or fact frames challenged by opposing factless frames) do not. This coheres with hypothesis 2c that the factual content is

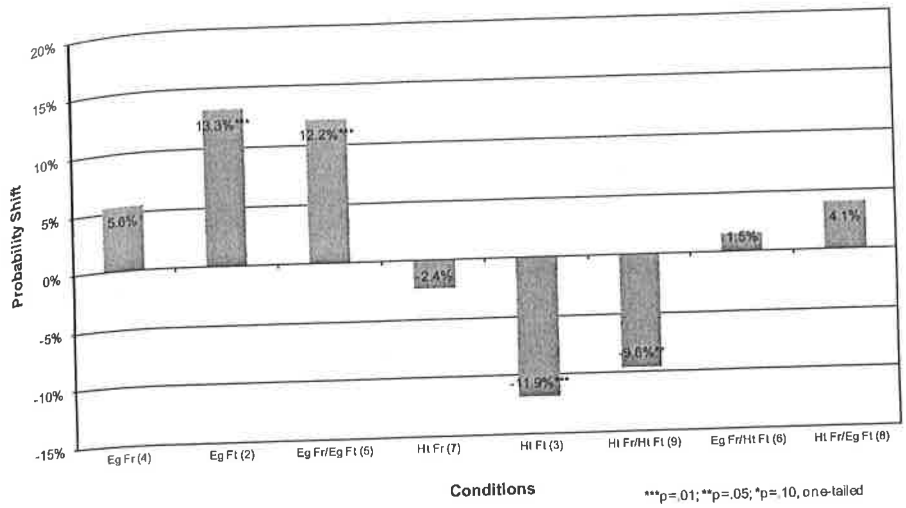

FIGURE 4.5. Behavior toward CNTs.

necessary to affect behavior (and, apparently, this content needs to be unchallenged).

Finally, Figure 4.6 displays the relative percentage effect of the given condition on the absolute difference between attitudes and behaviors. Negative scores show that there is a closer attitude–behavior link than that which appears in the control group. The results echo those in Figures 4.4 and 4.5, suggesting that the Figure 4.5 result showing behavioral effects (from the fact frames) reflects an increased link

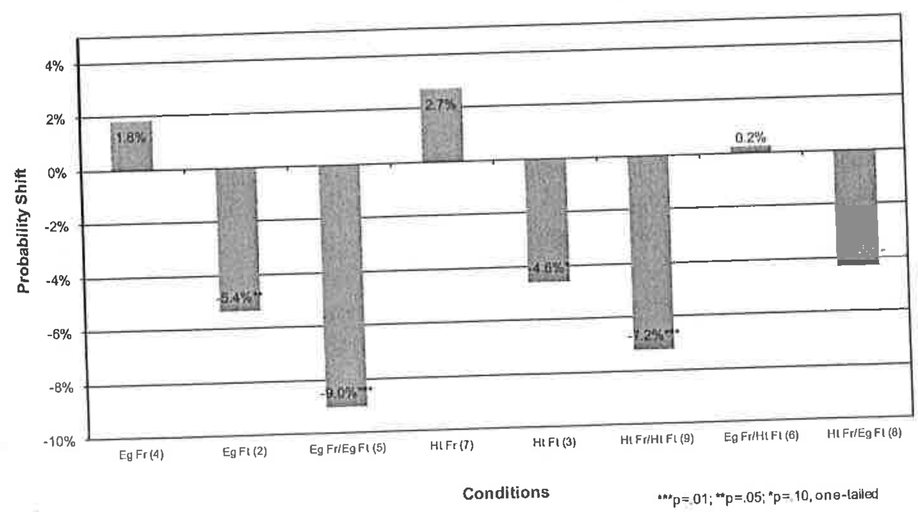

FIGURE 4.6. Attitude–behavior differences.

TABLE 4.3. *Determinants of attitude–behavior link*

Dependent variable: Absolute attitude–behavior difference (0 to 6)		
Experimental condition	Model 1	Model 2
Energy Frame (Pro Frame) (4)	.11 (.21)	.09 (.20)
Energy Fact (Pro Fact) (2)	−.32* (.21)	−.14 (.21)
Energy Frame/Energy Fact (Pro Frame/Pro Fact) (5)	−.54*** (.22)	−.38** (.21)
Health Frame (Con Frame) (7)	.16 (.21)	.09 (.21)
Health Fact (Con Fact) (3)	−.28* (.21)	−.15 (.20)
Health Frame/Health Fact (Con Frame/Con Fact) (9)	−.43** (.21)	−.32* (.21)
Energy Frame/Health Fact (Pro Frame/Con Fact) (6)	.02 (.22)	.01 (.21)
Health Frame/Energy Fact (Con Frame/Pro Fact) (8)	−.26 (.22)	−.17 (.21)
Attitude Certainty		−.19*** (.03)
Constant	1.23*** (.15)	2.00*** (.18)
R^2	.04	
Number of Observations	616	

Note: Entries are OLS coefficients with standard errors in parentheses. $^{***}p = .01$; $^{**}p = .05$; $^{*}p = .10$ for one-tailed tests.

between attitudes and behaviors. As hypothesis 2b suggests, the presence of a fact frame increases the link between attitude and behavior.[19]

Taken together, the results show that adding factual content to frames has *no* effect on attitudes, but does significantly increase the certainty with which attitudes are held, generate an effect on behaviors, and heighten the link between attitudes and behaviors. Facts, such as a reference to a scientific study, matter even if they do not have a direct attitudinal effect.

A final question is whether the results reflect a meditational process such that the increased attitude–behavior linkage stems from a higher degree of certainty; that is, does willingness to act on one's attitudes stem from increased certainty with which those attitudes are held (which in turn, as we have shown, stems from the presence of more certain factual information)? We test this with two regressions that appear in Table 4.3 (see Baron & Kenney, 1986). The dependent variable

[19] The largest effects are again in the factless frame–fact frame combination conditions (i.e., conditions 5 and 9), but again, these differences are not statistically significant and likely result from the dynamics reviewed in footnote 17.

for both equations is the absolute difference between attitudes and behaviors (see Figures 4.2 and 4.6). The first column focuses on the experimental conditions as independent variables and matches what Figure 4.6 shows: only the presence of factual information significantly links attitudes to behavior. The second column adds one independent variable: attitude certainty (which we know increases from the presence of factual knowledge). That certainty is highly significant and the conditions become insignificant or less significant is suggestive of the meditational view that the fact frames increase certainty, which in turn heightens the attitude–behavior link. It is this increased link that finally leads to the direct fact frame impact on behaviors.[20]

CONCLUSION

The question of whether factual information influences the public's reactions toward new technologies is central to debates about public perceptions of new innovations (e.g., Lee et al., 2005; Scheufele & Lewenstein, 2005; Kahan et al., 2007, 2008). Although most acknowledge that facts matter under some conditions for some people (see, e.g., Cobb, 2005), extant work has not pinpointed how these differences work over distinct types of public responses. We presented a theory and evidence that shows that adding facts to frames does *not* impact attitudinal support but *does* affect behavioral willingness to use the technology. Moreover, it influences behavior by (1) increasing attitudinal certainty, which in turn (2) heightens the link between attitudes and behaviors, and then (3) leads to increased behavioral effects. Notably, however, the impact of fact frames only occurs when they go unchallenged even by non-factual frames. In other words, one can mute the impact of the fact frames by countering them even with opposing factless frames.

More work is needed on distinct technologies, with more varied populations, in different settings. In so doing, it is critical that analyses draw a distinction between attitudes and behavior and consider the intervening role of attitude strength (e.g., certainty). Indeed, it would be a mistake to assume that technologies that receive support necessarily will be used, or that certain arguments that lack attitudinal effects will not influence usage. In other words, support does not automatically translate into usage; efforts to increase support need to explore more than basic attitudinal variables. As nanotechnology continues to expand, it becomes increasingly important to understand public reactions and how individuals treat distinct types of information. Only then can predictions be made about how varied nanotechnology applications will fare once they enter the public domain.

20 When we regress behavior on the conditions but then add the attitude–behavior difference variable, we find that the latter is highly significant. However, it does not render the experimental condition main effects insignificant and thus is not wholly mediating the condition effects.

APPENDIX

Scores By Condition

	No fact	Pro fact	Con fact
No Frame	(*Condition* 1) Attitude = 4.82 (SD: 1.01; n = 68) Certainty = 4.04 (SD: 1.75; n = 68) Behavior = 4.06 (SD: 1.76; n = 68) Difference = 1.23 (SD: 1.23; n = 68)	(2) Attitude = 5.54 (SD: 1.32; n = 69) Certainty = 4.97 (SD: 1.65; n = 69) Behavior = 4.86 (SD: 1.34; n = 69) Difference = 0.91 (SD: 1.07; n = 69)	(3) Attitude = 3.69 (SD: 1.61; n = 72) Certainty = 4.68 (SD: 1.56; n = 72) Behavior = 3.35 (SD: 1.44; n = 72) Difference = 0.95 (SD: 1.27; n = 72)
Pro Frame	(4) Attitude = 5.48 (SD: 1.22; n = 71) Certainty = 3.94 (SD: 1.76; n = 71) Behavior = 4.39 (SD: 1.57; n = 71) Difference = 1.34 (SD: 1.57; n = 71)	(5) Attitude = 5.32 (SD: 1.29; n = 68) Certainty = 4.91 (SD: 1.61; n = 68) Behavior = 4.79 (SD: 1.21; n = 67) Difference = 0.69 (SD: 0.97; n = 67)	(6) Attitude = 4.88 (SD: 1.48; n = 66) Certainty = 4.02 (SD: 1.90; n = 66) Behavior = 4.15 (SD: 1.68; n = 66) Difference = 1.24 (SD: 1.38; n = 66)
Con Frame	(7) Attitude = 3.89 (SD: 1.61; n = 70) Certainty = 3.67 (SD: 2.04; n = 70) Behavior = 3.91 (SD: 1.52; n = 69) Difference = 1.39 (SD: 1.27; n = 69)	(8) Attitude = 4.76 (SD: 1.14; n = 67) Certainty = 4.51 (SD: 1.71; n = 67) Behavior = 4.30 (SD: 1.77; n = 66) Difference = 0.97 (SD: 1.32; n = 66)	(9) Attitude = 3.37 (SD: 1.50; n = 68) Certainty = 4.63 (SD: 1.79; n = 68) Behavior = 3.49 (SD: 1.57; n = 68) Difference = 0.79 (SD: 1.03; n = 68)

SD = standard deviation.

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